PRODUCING WINTER WHEAT WITH CONSERVATION TILLAGE ON THE SOUTHEASTERN COASTAL PLAIN

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ABSTRACT

Producing winter wheat (Triticum aestivum L. em Thell) with conservation tillage has lagged behind most other major row crops on the southeastern Coastal Plain. Producer reluctance to use this practice has primarily been due to the lower wheat grain yields often obtained with conservation tillage. The objectives of our study were to (i) determine how conservation tillage affects winter wheat fertile tiller number per ft^2, number of kernels per tiller, and/or individual kernel weight and (ii) examine how different management practices affect wheat grain-yield responses to conservation tillage. Three separate field studies were conducted to test treatments of surface and deep tillage (Studies I, II, and III), direction and timing of deep tillage (Study III), fall N fertility rate (Study III), and crop rotation (Study II). In Studies I and II, average grain yield of wheat grown with conservation tillage was 6% less than the average grain yield of wheat grown with traditional tillage (disking). Lower grain yields with conservation tillage were associated with fewer plants per ft^2 after planting and fewer tillers per ft^2 at harvest. Deep tillage, a higher fall N fertility rate, and crop rotation all increased the number of tillers per ft^2 when the conservation tillage treatment was used, but usually not enough to compensate for its lower plant number per ft^2. The timing and direction of deep tillage had little effect on wheat grain yield and tiller number. Results from these studies indicate that obtaining an adequate number of fertile tillers per ft^2 is critical to the success of using conservation tillage for winter wheat production on the southeastern Coastal Plain..

INTRODUCTION

Use of conservation tillage for field-crop production has been steadily increasing in South Carolina over the past decade. A combination of both economic and environmental reasons has caused producers to switch from intensive tillage to conservation tillage, especially on the sandy Coastal Plain where the soils are inherently low in organic matter. In this Region, conservation tillage is especially beneficial during the summer months when the soil is frequently hot and dry (Frederick et al., 1998). The introduction of herbicide-tolerant varieties and the movement towards narrower row widths both have made weed control easier with conservation tillage and increased grower interest in this practice. In most cases, some type of deep tillage is usually necessary on the Coastal Plain to fracture naturally occurring hardpan layers which form just above the B soil horizon (Busscher et al., 1986). Deep-tillage implements with winged-subsoilers have been found to be well suited for use with conservation-tillage and narrow-row width systems (Frederick and Bauer, 1996; Frederick et al., 1998; Khalilian et al., 1991).

Planting winter crops, such as soft red winter wheat, with conservation tillage has lagged behind most other field crops. For example, in 2002, the percentage of South Carolina acres planted in conservation tillage was 19% for winter wheat (*Triticum aestivum* L.), 68% for doublecropped soybean (*Glycine max* L. Merr.), 46% for corn (*Zea maze* L.), and 33% for cotton (*Gossypium hirsutum* L.) [source: USDA-NRCS]. Producers have been reporting consistent lower grain yields when planting winter wheat with conservation tillage, compared to wheat grown with traditional surface tillage (Jay Chapin, 2003, personal communication). Part of this poor response may be due to the impact conservation tillage can have on seedbed conditions. Leaving plant residues on the soil surface generally results in cooler and wetter soils (NeSmith et al., 1987; Wilhelm et al., 1989), which may be advantageous for producing summer crops. However, low soil temperature and wet soils may have a negative impact on the early season growth and, consequently, final yield of winter crops such as wheat.

Winter wheat grain yield is very dependent on the number of kernels produced per ft^2 (Frederick and Bauer, 1999). Kernel number, in return, is determined by the number of fertile (seed-bearing) tillers per ft^2 and number of kernels per tiller. Thus, management practices that affect either of these two yield components should affect grain yield, unless an opposing change in kernel weight compensates for the change in kernel number (termed yield-component compensation). Tiller formation and development generally occur during the fall and early winter months in South Carolina. Tiller initiation at this growth stage is usually temperature dependent, with temperatures below optimum reducing the final number of tillers (Simmons, 1987). Soil water conditions are generally adequate at this time on the Coastal Plain, with drought usually occurring much later in the growing season (Frederick and Camberato, 1994, 1995a, 1995b). Thus, the cooler and wetter soil conditions generally associated with conservation tillage may be of little benefit or even detrimental to winter wheat, especially early in the growing season. If tiller initiation and development are hindered by these soil conditions and consequently, fertile tiller number ultimately reduced, then grain yields may be less with conservation tillage than with traditional surface tillage, as is commonly observed. During planting, if plant residues are not properly cut when the seed furrow is created, the residues may be pushed into the furrow ('pinning'), resulting in poor seed to soil contact and fewer emerged plants per ft^2. This effect may also reduce the number of tillers per ft^2 and, consequently, final grain yield.

If these negative effects on plant populations occur when producing winter wheat with conservation tillage, producers may be able to use other management practices to promote more tillers per plant or plants per ft^2. These practices may include delaying deep tillage until after planting to provide a firmer soil surface at planting, applying a greater amount of N fertilizer in the fall to promote tillering, and planting earlier in the fall when soil temperatures are warmer. Planting earlier may also give the plants more time for tiller initiation and development. The objectives of our research studies were to determine the impact of conservation tillage on winter wheat grain yield and yield components and to determine if additional management strategies are needed to alleviate the negative effect(s) conservation tillage may have on wheat yield components.

MATERIALS AND METHODS

Three separate research studies were conducted at the Pee Dee Research and Education Center near Florence, SC to determine the optimum tillage systems for producing winter wheat on the southeastern Coastal Plain. The studies are as follows:

Study I.

Soft red winter wheat (Northrup King cv. Coker 9134) was grown with two levels of surface tillage (disked and no surface tillage) and two levels of deep tillage (deep tilled and no deep tillage) during the 1993-1994 and 1994-1995 growing seasons on a Goldsboro loamy sand (fine-loamy, siliceous, thermic Aquic Kandiudult). Phosphorus and K fertilizer was applied before soil preparation in the fall at a rate based upon soil test results. Nitrogen was applied as ammonium nitrate at a rate of 30 lbs a^{-1} prior to planting in mid-November and at a rate of 50 lbs a^{-1} in the early spring at the stem erect growth stage. Appropriate plots were disked twice before planting to a depth of 6 in. After disking, the appropriate plots were deep tilled to a depth of 16 in (approximate depth to B soil horizon) using a four-shanked ParaTill. All plots were 10 feet wide and 50 feet long. Seed were planted with a John Deere 750 grain drill at a rate of 22 seeds ft^{-1} of crop row. Doublecropped soybean was grown after wheat harvest in all years using the same surface and deep tillage as used to produce the wheat crop. Wheat data collected included plant residue cover, plant number per ft^2 measured 3 weeks after planting, grain yield (13% moisture basis), and grain yield components (number of fertile tillers per ft^2, number of kernels per tiller, and individual kernel weight). All data collected in this study were subjected to analysis of variance as a randomized complete block design with four replications.

Study II.
Treatments in this study were very similar to Study I except treatments of soil type and crop rotation were also examined. Treatments included nonrotated winter wheat (Northrup King cv. Coker 9803) grown with all possible combinations of surface and deep tillage (disked/deep tilled, disked/no deep tillage, no surface tillage/deep tilled, and no surface tillage/no deep tillage) and rotated winter wheat (rotated with corn) that received the disked/deep tilled or no-surface-tillage/deep tilled treatments. The experiment was conducted between the 1996/1997 and 2000/2001 growing seasons. Soil fertility rates, equipment, and general production practices used were the same as described in Study I. All plots were 30 feet wide and 500 feet long so that each plot transected a number of different soil types common to the Coastal Plain region. Data collected included grain yield (13% moisture basis) and grain yield components (number of fertile tillers per m^2, number of kernels per tiller, and individual kernel weight). All data collected in this study were subjected to analysis of variance as a randomized complete block design with three replications.

Study III.
Soft red winter wheat (cv. Northrup King Coker 9663) was produced with treatments of timing of deep tillage (before planting, after planting, and no deep tillage), direction of deep tillage (parallel to versus at a 7^o angle across the wheat rows), fall N fertility rate (30 and 60 lbs N a^{-1}) and surface tillage (double disking and no surface tillage) during the 1999/2000 and 2000/2001 growing seasons. The different treatments are shown in Table 1. All wheat was grown no till except for in the second year of the study when the disked treatments were introduced. For the disked treatments, deep tillage was done after planting at a 7^o angle to the wheat rows. Soil fertility rates, equipment, and general production practices used were the same as described in Study I except a Krause 5500 no-till grain drill was used to plant the wheat. All plots were 15 feet wide and 50 feet long. Data collected included plant number per ft^2 measured 3 weeks after planting, grain yield (13% moisture basis), and grain yield components (number of fertile tillers per m^2, number of kernels per tiller, and individual kernel weight). All data collected in this study were subjected to analysis of variance as a randomized complete block design with four replications.

RESULTS AND DISCUSSION

In study I, using conservation tillage decreased seedling emergence by an average of 16%, compared to wheat grown in the disked plots (Table 2). In contrast to what was expected, deep tillage had no effect on plant number per ft^2. We hypothesized that deep tillage would reduce plant number by way of creating a soft seed bed at the time of planting, allowing residues to be pushed into the seed furrow at planting (pinning) and reducing seed-to-soil contact and seedling emergence. Study I was one of the first winter wheat conservation-tillage studies that we conducted. In this study, only an average of 62% of the seed planted in the conservation tillage plots emerged (data not shown). We planted to a depth of about 1.25 – 1.50 inches in this study, which is the recommended seeding depth when using traditional tillage practices. However, we visually observed that many of the seeds were intermixed with plant residues in the seed furrow when the conservation-tillage treatment was used (for both deep tilled and no deep tillage plots), resulting in poor seed to soil contact and poor germination. Previous research conducted in the early 1990s on the Coastal Plain also reported poor plant populations for wheat planted with conservation tillage (Karlen and Gooden, 1997). In subsequent experiments (including Studies II and III), we planted to a depth of 2.0 inch which allowed most of the seed to be placed into the soil below the plant residues, especially when the seed was planted in plots having no deep tillage.

In Study I, fertile tiller number per ft^2 and grain yield were similar for the disked and conservation-tillage plots (Table 2). This finding indicates that the wheat grown with conservation tillage compensated for its fewer number of plants per ft^2 by producing more tillers per plant. Grain yields were higher with conservation tillage than with disking in the second year of Study I when a prolonged period of drought stress began during the stem elongation stage of development. In that year, wheat grown with conservation tillage had a greater number of kernels per tiller than the wheat grown in the disked plots (data not shown). In Study I, deep tillage increased the number of tillers per ft^2 and individual kernel weight (Table 2) but had little effect on kernel number per tiller (data not shown). In Study II, both grain yield and tiller number per ft^2 were less with conservation tillage than traditional tillage in most years of the study, both with and without deep tillage (Table 3). Surface tillage had little effect on the number of kernels per tiller in Studies I or II (data not shown) and only a slight positive effect on kernel weight in Study I (Table 2). Increases in winter-wheat yield due to crop rotation were also due to increases in tiller number per ft^2 (Table 3).

In Study III, plant number per ft^2 was greatest for the conservation tillage/no deep tillage treatment (Table 4). Deep tillage reduced plant number per ft^2, with a greater reduction occurring when deep tillage was done after planting compared to before planting. Over all deep tillage treatments, plant number per ft^2 was lower for the plots that were disked, compared to those that were not. The lower plant populations in the disked plots were due to the severe surface crusting that resulted from compaction caused by the roller bar on the ParaTill (plots were deep tilled after planting) which prevented many seedlings from emerging. This unexpected response suggests that deep tillage should not be done after planting if the soil surface is disked. Deep tillage and applying a higher fall N fertility rate both increased the number of fertile tillers per ft^2. There was little effect of the tillage treatments on the number of kernels per tiller or on individual kernel weight (data not shown).

CONCLUSIONS

Compared to disking the soil, the lower winter wheat yields with conservation tillage in our study were primarily due to fewer emerged plants early in the growing season. The poorer plant population with conservation tillage usually resulted in fewer fertile tillers per ft^2 at harvest. However, in cases where the wheat plants were able to compensate for the fewer emerged plants by producing more tillers per plant, grain yields did not differ for the disked and conservation-tillage treatments. With conservation tillage, increasing the fall N fertility rate stimulated tillering and helped compensate for its lower plant numbers. We also found that management practices such as deep tillage and crop rotation were of greater benefit to the wheat grown with conservation tillage than the wheat grown with traditional tillage. Results from our studies indicate that future success of producing winter wheat with conservation tillage on the southeastern Coastal Plain will depend upon developing management strategies to obtain higher tiller numbers per unit land area.

REFERENCES

Busscher, W.J., R.E. Sojka, and C.W. Doty. 1986. Residual effects of tillage on Coastal Plain soil strength. Soil Sci. 141:144-148.

Frederick, J.R. and P.J. Bauer. 1999. Physiological and numerical components of wheat yield. p. 45-84. *In* E.H. Satorre and G.A. Slafer (ed.) Wheat – Ecology and physiology of yield determination. Food Products Press, New York, NY.

Frederick, James R., and Philip J. Bauer. 1996. Winter wheat responses to surface and deep tillage on the southeastern Coastal Plain. Agron. J. 88:829-833.

Frederick, J.R., and J.J. Camberato. 1994. Leaf net CO2-exchange rate and associated leaf traits of winter wheat grown with various spring nitrogen fertilization rates. Crop Sci. 34:432-439.

Frederick, J.R., and J.J. Camberato. 1995a. Water and nitrogen effects on winter wheat in the southeastern Coastal Plain. I. Grain yield and kernel traits. Agron.J. 87:521-526.

Frederick, J.R., and J.J. Camberato. 1995b. Water and nitrogen effects on winter wheat in the southeastern Coastal Plain. II. Physiological responses. Agron. J. 87:527-533.

Karlen, D.L., and D.T. Gooden. 1987. Tillage systems for wheat production in the southeastern Coastal Plain. Agron. J. 79:582-587.

Khalilian, A., C.E. Hood, J.H. Palmer, T.H. Garner, and G.R. Bathke. 1991. Soil compaction and crop response to wheat/soybean interseeding. Trans. ASAE 34:2299-2303.

NeSmith, D.S., W.L. Hargrove, D.E. Radcliffe, E.W. Tollner, and H.H. Arioglu. 1987. Tillage and residue management effects on properties of an Ultisol and double-cropped soybean production. Agron. J. 79:570-576.

Simmons, S.R. 1987. Growth, development, and physiology. p. 77 – 113. In E.G. Heyne. Wheat and wheat improvement, Second Edition. Amer. Soc. Agron. Monograph no. 13, Madison, WI.

Wilhelm, W.E., H. Bouzerzour, and J.R. Power. 1989. Soil disturbance-residue management effect on winter wheat growth and yield. Agron. J. 81:581-588.

Table 1. Production practices used for each deep tillage system in Study III. Practices used included surface tillage (none versus disking), timing of deep tillage (before versus after planting), direction of deep tillage (parallel to crop rows versus across rows), and fall N fertility rate. Deep-tillage systems where the soil was disked (systems 7 and 8) were only used during the second growing season (2000/2001).

Surface Tillage	Timing of Deep Tillage	Direction of Deep Tillage	Fall N Rate	System Number
			lbs $acre^{-1}$	
None	Before	Parallel	30	1
None	Before	Across	30	2
None	After	Parallel	30	3
None	After	Across	30	4
None	None	None	30	5
None	Across	Across	60	6
Disked	Across	Across	30	7
Disked	Across	Across	60	8

Table 2. Wheat seedling number, grain yield, tiller number per ft^2, and individual kernel weight as affected by surface and deep tillage treatments in 1994 and 1995.

Tillage		Seedling No.		Grain Yield		Tiller Number		Kernel Weight	
Surface	Deep	1994	1995	1994	1995	1994	1995	1994	1995
		-------ft^{-2}--------		----bu $acre^{-1}$-----		-------ft^{-2}--------		--mg $kernel^{-1}$--	
No-till	No	18.5	25.0	54.0	42.3	41.2	33.1	26.9	26.1
No-till	Yes	19.2	25.3	67.2	61.9	51.7	36.3	28.3	27.2
Disked	No	26.6	27.1	59.3	39.1	51.1	29.3	25.9	25.7
Disked	Yes	24.7	26.3	66.6	49.6	51.0	34.5	28.7	27.0
Effect									
Surface tillage		**	**	**	**	**	*	NS	NS
Deep tillage		NS	NS	**	**	**	**	**	**
Interaction		NS	NS	**	*	**	NS	NS	NS
LSD (0.05)		NS	NS	3.7	6.5	2.7	NS	NS	NS

*,** Significant at the 0.05 and 0.01 probability levels, respectively.
LSD is for comparison of interaction means.

Table 3. Winter wheat grain yield and tiller number per ft^2 as affected by surface tillage, deep tillage, and crop rotation (continuous wheat versus rotated with corn) in years 1997 through 2001. Tiller numbers per ft^2 are shown in parentheses.

Tillage			Grain Yield (Tiller Number)				
Surface	Deep	Rotated	1997	1998	1999	2000	2001
			---------------------bu $acre^{-1}$ (no. ft^{-2})----------------------				
Disked	Yes	No	63 (43.9)	42 (41.3)	33 (36.1)	40 (36.5)	21 (26.1)
Disked	No	No	51 (37.8)	37 (35.5)	22 (33.7)	34 (34.7)	9 (22.8)
No-Till	Yes	No	60 (42.7)	39 (37.3)	26 (33.3)	36 (35.9)	17 (27.7)
No-Till	No	No	46 (35.5)	27 (34.2)	19 (30.7)	29 (31.2)	7 (21.6)
No-Till	Yes	Yes	--	--	41 (41.4)	--	26 (28.2)
Disked	Yes	Yes	--	--	41 (41.0)	--	31 (31.4)
LSD			6 (3.6)	4 (2.7)	4 (2.8)	4 (3.9)	3 (2.9)

Fisher=s protected LSD test at P = 0.05.
Presence of LSD indicates deep-tillage-system effect was significant at 0.05 probability level.

Table 4. Winter wheat plant number per ft^2, grain yield, and fertile tiller number per ft^2 as a function of deep-tillage cropping system during the 2000 and 2001 growing seasons. Production practices used for each deep-tillage system are shown in Table 1.

	Plant Number		Grain Yield		Tiller Number	
System	2000	2001	2000	2001	2000	2001
	----------no. ft^{-2}----------		--------bu $acre^{-1}$---------		----------no. ft^{-2}----------	
1	34.0	34.3	50.0	49.9	44.4	43.8
2	34.1	34.7	55.0	49.5	43.5	44.8
3	32.1	31.6	53.0	52.3	41.2	45.4
4	31.8	31.1	59.5	52.8	43.2	42.5
5	35.5	35.8	47.3	44.5	37.6	39.9
6	30.6	28.5	72.1	58.2	54.2	52.8
7	--	23.2	--	46.9	--	39.8
8	--	23.7	--	57.3	--	52.4
LSD(0.05)	2.5	3.7	4.3	5.7		4.3

Fisher=s protected LSD test at P = 0.05.
Presence of LSD indicates deep-tillage-system effect was significant at 0.05 probability level.